Solving Environmental Problems Using a Multi-Agency Approach: The Interagency DNAPL Consortium (IDC)

Laymon L. Gray (lgray@opus.freac.fsu.edu)
Institute for International Cooperative Environmental Research
Florida State University
2035 East Paul Dirac Drive - Suite 226 Morgan Bldg.
Tallahassee, Florida 32310-3700

Thomas O. Early, Ph.D. (eot@ornl.gov)
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6400

Introduction

The greatest barrier to deploying innovative remediation technologies is "risk". The risk that the technology will not meet required performance goals of the regulators and stakeholders. The risk that the cost of implementation will exceed estimates by a wide margin. The risk that application of the process itself will somehow lead to a worsening of the environmental problem being addressed. Environmental restoration managers generally are "risk adverse". They may be willing to spend more money and allow more time for cleanup of an environmental problem by using a baseline technology with a long track record in order to have the confidence that it will perform in a predictable way. This is especially true if there are several innovative technologies to choose among and no objective basis on which to make a comparison other than the claims of the vendors. This approach is a trade-off between the *known* cost and operational characteristics of a baseline method against the *potential* cost and performance benefits of what are perceived to be unproven technologies.

The reality of risk aversion within DOE is further reinforced if we consider that the award fees for the increasingly common management and integration contractors are based largely on meeting schedules for contamination cleanup activities. Likewise, lower-tier subcontractors frequently are receiving fixed-fee, performance-based contracts that specify the performance that must be achieved without prescribing the remedy. There is little incentive in this contracting environment to use innovative technologies. Therefore, the challenge to DOE is to greatly reduce the risk to end-users of deploying new technologies.

The National Research Council examined many of the barriers to stimulating development and commercialization of innovative technologies and offers recommendations to overcome these barriers (NRC, 1997). Recommendations include ways to stimulate markets, improve the quantity and availability of technology performance and cost data, and improve testing programs and generally address the issue of perceived risk associated with deploying innovative technologies. It is strongly believed that the pre-deployment testing program outlined in this paper embraces many of the features covered by the NRC report because it incorporates more extensive and rigorous technology testing than currently done with a formal program of cost and performance documentation and reporting.

Objective/Problem

Dense Non-Aqueous Phase Liquids (DNAPLs) pose serious, long-term groundwater contamination problems due to their toxicity; limited solubility in groundwater; and significant migration potential in soil gas, groundwater, and/or as separate phase liquids. DNAPL chemicals, particularly chlorinated solvents, are among the most common of environmental contamination problems in the United States as well as for most industrialized countries. There are thousands of DNAPL-contaminated sites in the United States, often at contaminant volumes that are difficult to detect, but in quantities that can represent significant sources of groundwater contamination. Many agency and private-sector sites have DNAPL contamination problems, including federal, state and local government agencies. The Office of Management and Budget estimates that the federal government alone will spend billions of dollars for environmental clean-up of DNAPL contamination problems.

While various DNAPL remediation, characterization and monitoring technologies have been demonstrated in the past, it is difficult, if not impossible, to make meaningful comparisons of either performance or cost among these technologies because of the variable conditions at the demonstration sites. As a result, “problem holders” and regulatory officials have been reluctant to deploy these technologies for site clean up. In order to expedite the regulatory acceptance and use of these innovative remedial technologies, comparative cost and performance data must be collected. This project was designed to obtain those data for one selected site.

An important step in reducing technology risk and increasing user and regulatory acceptance of DNAPL remediation characterization and monitoring technologies involves conducting concurrent "side-by-side" field demonstrations. These side-by-side demonstrations result in comparative cost and performance data collected under the same field conditions. Through appropriate documentation, the resulting cost and performance data can be evaluated for site specific applications. Side-by-side demonstrations help to fill an important "gap' in the process of technology development and deployment and will accelerate technology privatization.

Approach/Solutions

In 1997, representatives from DOE and the USAF (AFRL) began discussing the concept of conducting side-by-side demonstrations of several promising, innovative DNAPL remediation technologies. Preliminary funding commitments were made by the two agencies. One of the first steps in achieving the objectives of this project was to identify a suitable site for the demonstrations. A variety of federal sites were considered before deciding upon a location at launch Complex 34 at cape Canaveral, Florida. This site has numerous benefits that led to its selection, including a relatively porous and permeable lithology and a single DNAPL contaminant (TCE) located at relatively shallow depths (<50 ft) in the saturated zone.

In order to finalize the site selection process, initial screening for DNAPL was conducted by the Savannah River Technology Center and Florida State University on behalf of DOE between February and June of 1998. During these activities, extensive soil and groundwater samples were collected and analyzed. Based on the results of this investigation, extensive DNAPL contamination was discovered and the site was selected for the side-by-side demonstrations.

In early 1998, a multiagency consortium (Interagency DNAPL Consortium - IDC) was organized by the United States Department of Energy/Office of Environmental Management (DOE/EM) and the Department of Defense (DOD) through the Air Force Research Laboratory (AFRL) and the 45th Space Wing in cooperation with the National Aeronautics and Space Administration (NASA) and the United States Environmental Protection Agency (EPA) to demonstrate innovative DNAPL remediation and characterization technologies at a NASA remediation site on Cape Canaveral Air Station, Cape Canaveral, FL. The IDC was formed to:

- address a serious, widespread and shared environmental problem adversely affecting many U.S. federal agencies (e.g., DOE, EPA, DOD, NASA, Department of Interior, Department of Agriculture);

- cost-share the demonstration and comparison of these remediation and monitoring system technologies;

- accelerate both the demonstration and deployment of DNAPL remediation, characterization and monitoring technologies for the purpose of reducing the perceived technology risk associated with these technologies;

- increase regulatory and user acceptance of these technologies by providing documented, cost and performance data; and

- provide increased opportunities to test new sensors designed to support *in situ* remediation of DNAPL contamination problems in addition to *ex situ* treatment and disposal.

In order to conduct this side-by-side demonstration, a Core Management

Team was organized of representatives from the partnering agencies. The Team is a collaborative decision-making body that draws upon the strengths of each agency to solve problems associated with the project. The Team utilizes a Technical Advisory Group (TAG) for support in making decisions that concern individual evaluation of remediation systems. The TAG is comprised of experts from industry, academia and federal agencies with broad experience in DNAPL remediation technologies. With the support of the TAG, the Team selected three of the most promising remediation technology groups as suitable for the site and solicited proposals from the private sector (*in situ* oxidation, *in situ* flushing and *in situ* heating).

Remediation goals for the demonstrations were based on the compliance requirements of the host site. Detailed cost and performance data will be collected, analyzed and compared so that, following the demonstration, site owners, regulators and stakeholders can make informed decisions regarding site remediation. If any technology meets the host site's performance and cost metrics, the technology will be considered for full-scale remediation.

Day-to-day on-site field management is provided for the Team by Florida State University's Institute for International Cooperative Environmental Research through a cooperative agreement with the Department of Energy.

Following award of the design contracts, the IDC undertook a more extensive site characterization of the demonstration sites to determine the lateral and vertical extent of DNAPL contamination and to obtain an estimate of the mass of TCE present in each of the test cells. During February of 1999, Battelle, the U.S. Environmental Protection Agency and Florida State University conducted a source zone characterization of the sites. Field activities focused on the region adjacent to and under the Engineering Support Building (ESB). When the Launch Complex was active, the ESB was use for cleaning rocket engine components and spent TCE was disposed of through floor drains and a clay pipe that discharged at grade near the building. These activities appear to be responsible for the DNAPL contamination at the site. Based on the results of these characterization activities, the following mass of TCE was estimated each treatment cell:

Stratigraphic Unit	**Six Phase Heating Cell**		**Steam Cell**		**Oxidation Cell**	
	Total (kg)	**NAPL (kg)**	**Total (kg)**	**NAPL (kg)**	**Total (kg)**	**NAPL (kg)**
Upper Sand Unit	183	70	464	165	846	601
Middle Fine - Grained Unit	611	447	639	399	1048	748
Lower Sand Unit	1,059	9,973	11,973	11,149	4,228	3,689
Total	11,313	10,490	13,077	11,713	6,122	5,039

Kilogram-kg
Non Aqueous Phase Liquid-NAPL
Information supplied by Battelle

Project Description: Evaluation of Remediation Technologies

Six Phase Soil Heating

The Six Phase Soil Heating Technology removes contaminants from soil and ground water by passing electrical current through the soil matrix. The passage of current generates heat due to electrical resistance within the soil. This is the same process used in any electrically heated device (e.g., clothes iron, heater, stove). Heat is generated throughout the soil in the remediation area and the temperature of the soil is increased to the boiling point of water. Soil moisture becomes steam that is captured by vapor recovery wells for removal. Soil contaminants are vaporized concurrently and are captured for *ex situ* treatment.

Benefits

- Heat is generated uniformly throughout the treatment volume. While low permeability lenses reduce the performance of other technologies that rely on the vertical movement of a fluid or vapor though the soil matrix, soil heterogeneity or low permeability does not adversely effect Six Phase Soil Heating. In fact, low permeability soils tend to carry greater current than do sandy soils, thus, become hotter, and boil constituents faster.

- Anaerobic dechlorination of solvents will add conductive chloride ions to "hot spots", likewise attracting current for faster remediation of the impacted regions of the site.

- The boiling of soil moisture in clay lenses forms steam to "sweep out" volatile organic compounds. This steam stripping process effectively increases the permeability of clay soils.

- Because Six Phase Soil Heating treats all soils in the treatment volume, there are no untreated regions from which contaminants could diffuse later and cause rebound. Rebound has not been observed at any Six Phase Soil Heating site.

- The presence of perched water does not reduce the effectiveness of Six Phase Soil Heating.

Chemical Oxidation with Permanganate

In situ oxidation using potassium permanganate is a potentially fast and low cost solution for the destruction of chlorinated ethylenes (TCE, PCE, etc), BTEX (benzene, toluene, ethylbenzene, and xylene) and simple polycyclic aromatic hydrocarbons. In particular, potassium permanganate reacts effectively with the double bonds in chlorinated ethylenes such as trichloroethylene, perchloroethylene, dichloroethylene isomers, and vinyl chloride. It is effective for the remediation of DNAPL, adsorbed phase and dissolved phase contaminants and produces innocuous breakdown products such as carbon dioxide, chloride ions and manganese dioxide. The permanganate solution typically is applied at concentrations of one to three percent solution via injection wells. This solution is easily handled, mixed and injected and is non-toxic and non-hazardous.

Bench scale laboratory tests of potassium permanganate with trichloroethylene have resulted in up to a 90% reduction of trichloroethylene in four hours of treatment. The effectiveness of the *in situ* injection of permanganate is a function of the reaction kinetics, the transport and contact between potassium permanganate and the contaminant, as well as competitive reactions with other oxidizable species (e.g., iron, natural organics). The effective use of this remedial technology requires an engineered approach for maximizing the contact between potassium permanganate and the target contaminant. As with many technologies, low permeability and heterogeneity of soils present a challenge and require a carefully designed application system.

Benefits

- Chemically oxidizes a wide range of organic compounds to innocuous end products over a wide pH range.

- Visible (purple) solution makes it easy to track the injection influence or the degree of treatment.

- Chemically stable in water (very slow auto-degradation) — stays in solution until it is reacted, no off-gas treatment required.

Thermal Remediation (Steam Injection)

Thermal remediation by steam injection and recovery uses Dynamic Underground Stripping, Steam Enhanced Extraction, Hydrous Pyrolysis/Oxidation, and Electrical Resistance Tomography. Combining these technologies the Dynamic Underground Stripping System uses boilers to generate steam which is then pumped into injection wells that surround the contaminants. The steam front volatilizes and mobilizes the contaminants as it pushes the resulting steam front toward a central network extraction well where it is vacuumed to the surface. Direct electrical heating of soils, clay and fine-grained sediments causes trapped water and contaminants to vaporize and forces them into steam zones where vacuum extraction removes them. Electrical Resistance Tomography is used as a process control method to measure electric resistance and temperatures in the subsurface that allow for real-time control of the heating process.

Benefits

- Faster clean-up, potential closure within months to years, not decades.

- Removes source contaminants effectively.

- Treats contamination both above and below the water table, with no practical depth limitation.

Sensor Technology Evaluations

In addition to DNAPL remediation technology demonstrations, the project provides the opportunity to evaluate innovative characterization technologies for locating DNAPL, *in situ* lithologic mapping, *in situ* vadose zone and saturated zone sampling and *in situ* hydraulic conductivity measurements. These technologies were deployed using the DOE and EPA Site Characterization and Analysis Penetrometer System (SCAPS) trucks. In addition to sensor technology evaluation, the SCAPS trucks have been used for data collection essential to conceptual model design and strategic location of critical lithologic units, sediment sampling and monitoring well placement. The following cone penetrometer (CPT) based sensors and sampling tools have been deployed at the Site.

Benefits

- Raman spectroscopy: used for direct detection of DNAPL in the subsurface.

- GeoVIS: soil video imaging system used for visual characterization of critical stratigraphic units and visual detection of DNAPL.

- Cone Permeameter™: *in situ* permeability measurements.

- ConeSipper®: multiple depth discrete soil gas and groundwater sampling.

- FLUTE: Hydrophobic Flexible Membrane is a sampling device that can provide detailed delineation of DNAPL in a borehole.

- Precision Injection/Extraction (PIX) Probe: characterization method for determining the presence or absence of depth discrete DNAPL.

Future Activities

Battelle and U.S. EPA have developed quality assurance project plans to assure that the characterization and technology demonstrations are conducted under scientific conditions and that technical and cost performance data collected during the demonstrations are scientifically valid. Following the conclusion of the demonstrations, final reports will be prepared that will detail the cost and performance of these technologies. These reports are scheduled for completion in September of 2000.

Based on the anticipated successful results of these side-by-side technology evaluations, it is recommended that the approach taken by the IDC should be emulated to address other environmental problems shared by U.S. Federal agencies. In addition, the prospects and advantages of broadening participation to the international community should also be evaluated and implemented where appropriate.

References

NRC (1997). Innovations in Ground Water and Soil Cleanup: From Concept to Commercialization. National Research Council, National Academy Press, Washington, D.C.

Additional Project Information

To obtain additional information for the IDC project, the following list of individuals is provided.

Mr. Skip Chamberlain
U.S. Department of Energy
(Germantown, Maryland)
(301) 903-7248
grover.chamberlain@em.doe.gov

Mr. Jim Wright
U.S. Department of Energy
(Aiken, South Carolina)
(803) 725-5608
jamesb.wright@srs.gov

Major Paul B. DeVane
U.S. Air Force Research Laboratory (Tyndall AFB, Florida)
(850) 283-6288
paul.devane@mlq.afrl.af.mil

Mr. Thomas Holdsworth
U.S. Environmental Protection Agency (Cincinnati, Ohio)
(513) 569-7675
holdsworth.thomas@epamail.epa.gov

Dr. Jackie Quinn
National Aeronautics and Space Administration (Kennedy Space Center, Florida)
(407) 867-4265
Jacqueline.Quinn
1@ksc.nasa.gov

Mr. Ed Worth
U.S. Air Force 45th Space Wing
(Patrick Air Force Base, Florida)
(407) 853-0965
edwin.worth@pafb.af.mil

IDC Home Page
http://gemini.getf.org/dnapl

Contract Information

Research sponsored by the U.S. Department of Energy's Federal Energy Technology Center, under Contract DE-FC21-95EW55101 with the Florida State University, 2035 East Paul Dirac Drive - Suite 226 Morgan Bldg., Tallahassee, Florida 32310-3700, rherndon@mailer.fsu.edu.

Acknowledgement Information

The guidance provided by Mr. Karl-Heinz Frohne, FETC COR for this cooperative agreement during the period of performance (12/01/98 to 11/30/99), is acknowledged and greatly appreciated.